CREEP BEHAVIOUR AND STRENGTH OF MAGNESIUM-BASED COMPOSITES

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OUTLINE

- Introduction
- Short – fibre reinforced AZ 91 and QE 22 alloys (squeeze casting)
- Particle-reinforced QE 22 alloy (powder metallurgy)
- Conclusions

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Mg – BASED METAL MATRIX COMPOSITES

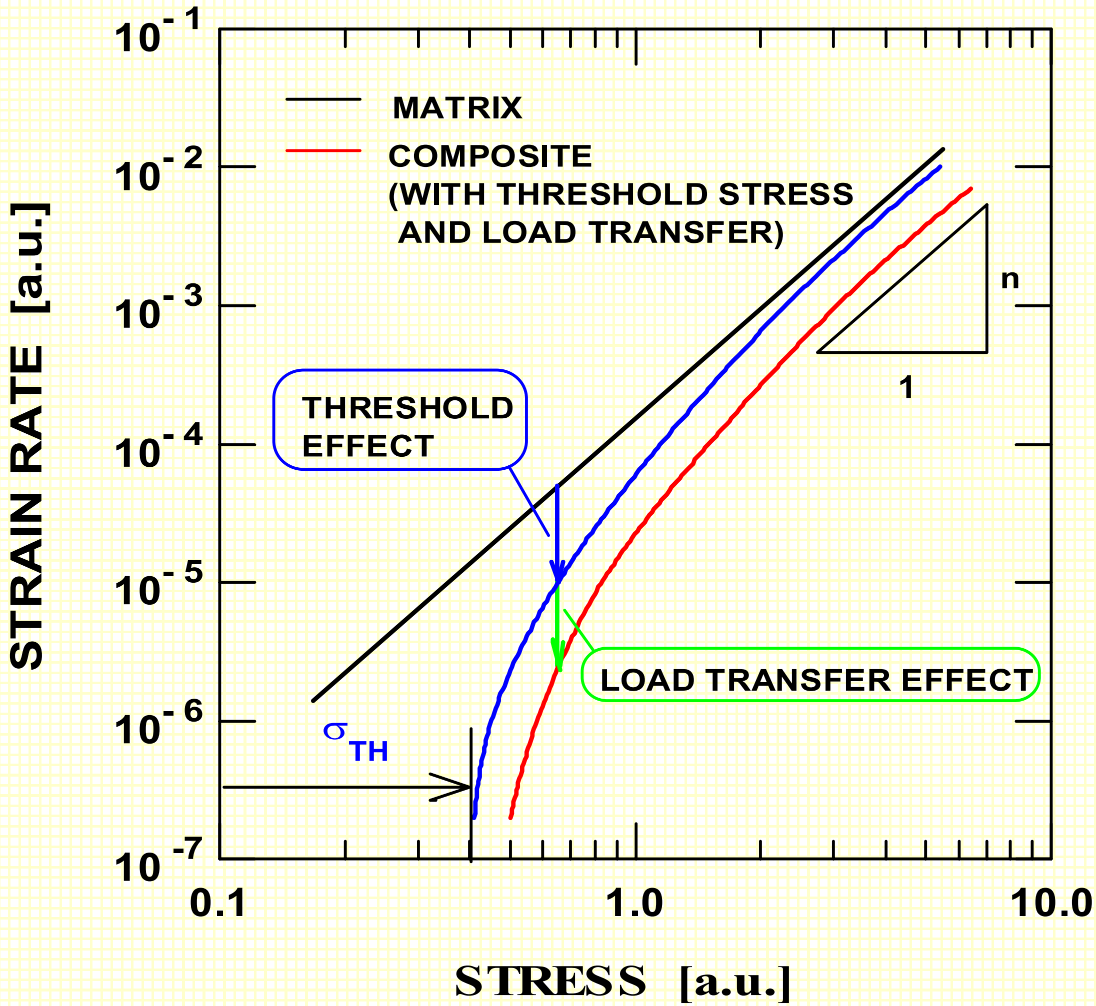
The property profile achieved is determined by:

the raw materials used

the production procedures

- matrix alloy
- nature of reinforcement (fibres, particles, …)
- chemical composition of reinforcement
- morphology, volume fraction and distribution of reinforcement
- manufacturing process
- subsequent treatment

COMPOSITE STRENGTHENING EFFECTS IN CREEP



EXPERIMENTAL MATERIALS

TU Clausthal, Germany – squeeze casting

AZ 91 MAGNESIUM ALLOY

composition: 9wt%Al+1wt%Zn+0.3wt%Mn

AZ 91 – 20 vol%Al_2O_3(f) COMPOSITE

20 vol% of Saffil δ - Al_2O_3 fibres

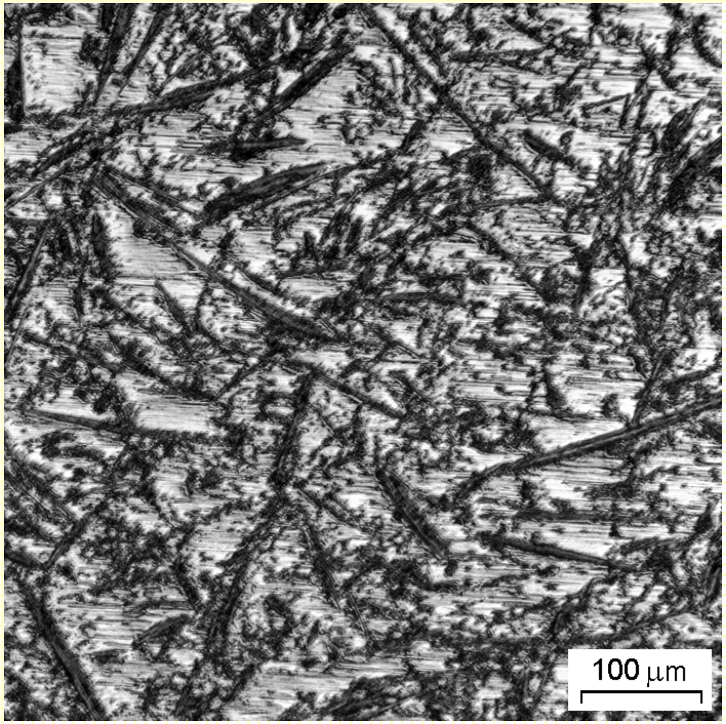
diameter ~ 3 μm, length 1 ~ 100 μm

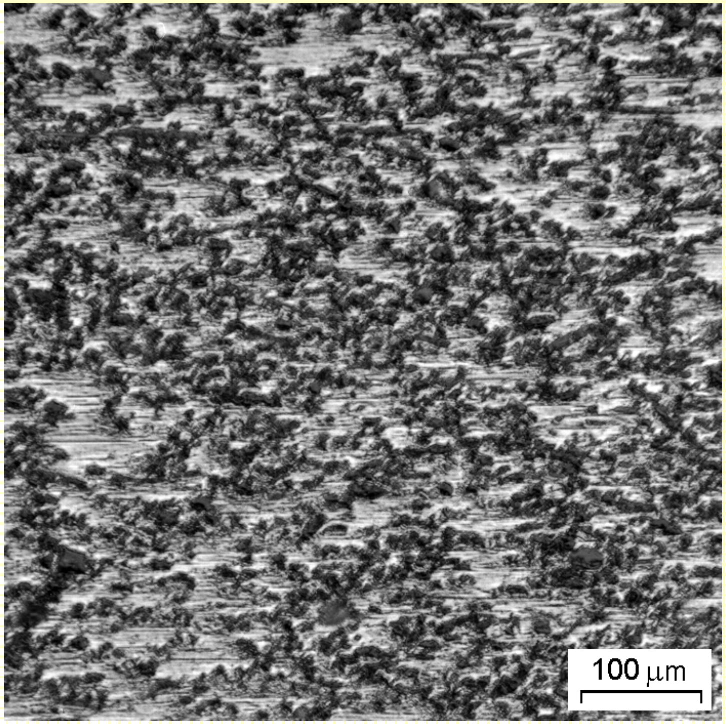
planar random distribution

T6 heat treatment annealing: 688 K/ 24h

ageing: 443 K/ 24h

AZ 91 – 20 vol.% Al_2O_3 composite





Optical micrographs showing microstructure of the composite in two perpendicular directions

EXPERIMENTAL MATERIALS (cont.)

QE 22 MAGNESIUM ALLOY

composition: 2.5wt%Ag+2.0wt%Nd rich rare earths+0.6wt%Zr

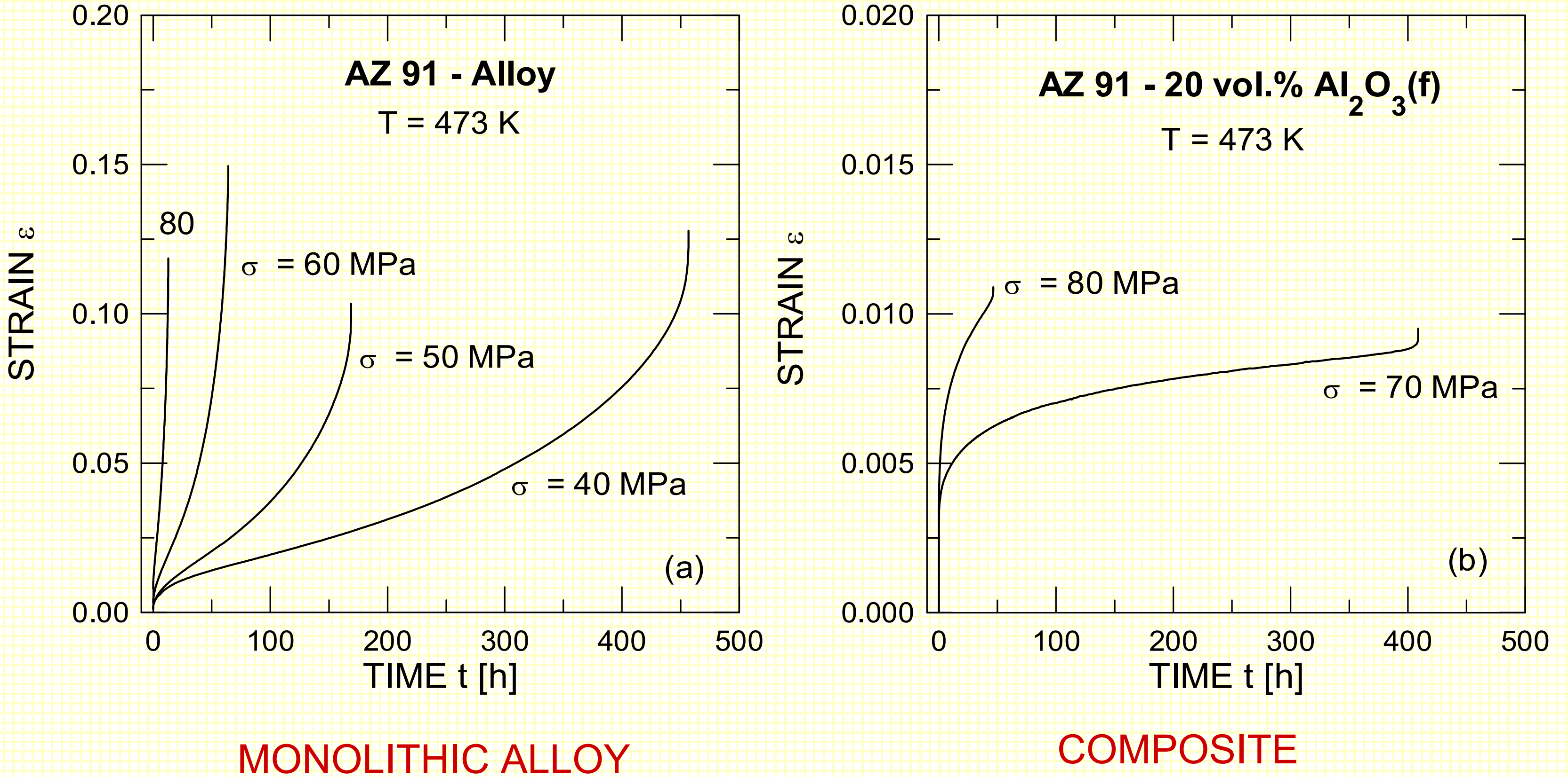
QE 22 – 20 vol%Al_2O_3(f) COMPOSITE

T6 heat treatment annealing: 803 K/ 6h
ageing: 447 K/ 8h

CREEP TESTING

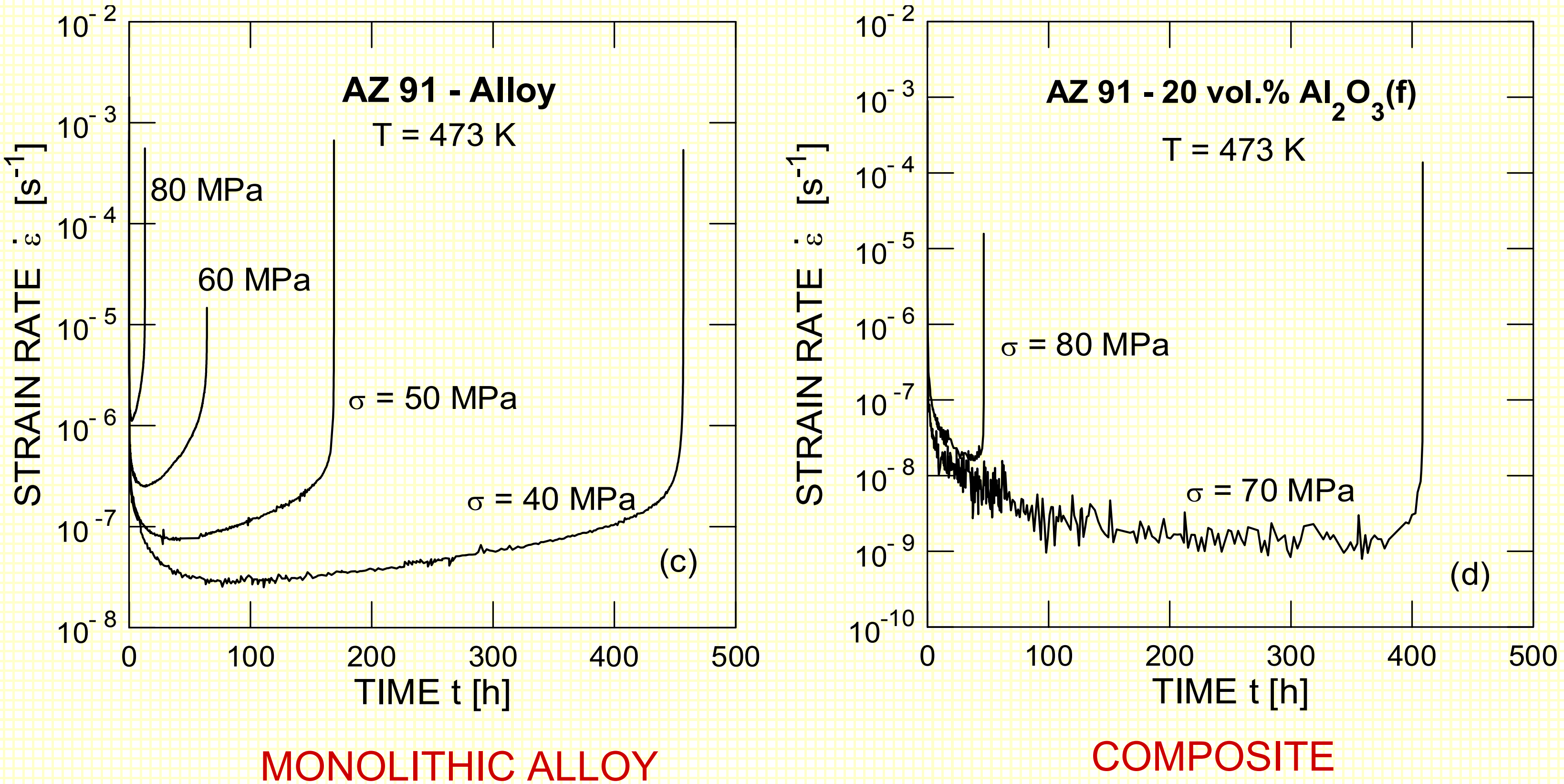
- constant stress tensile creep tests
- testing temperatures: from 423 to 523 K
- applied stresses: from 10 to 200 MPa

CREEP CURVES



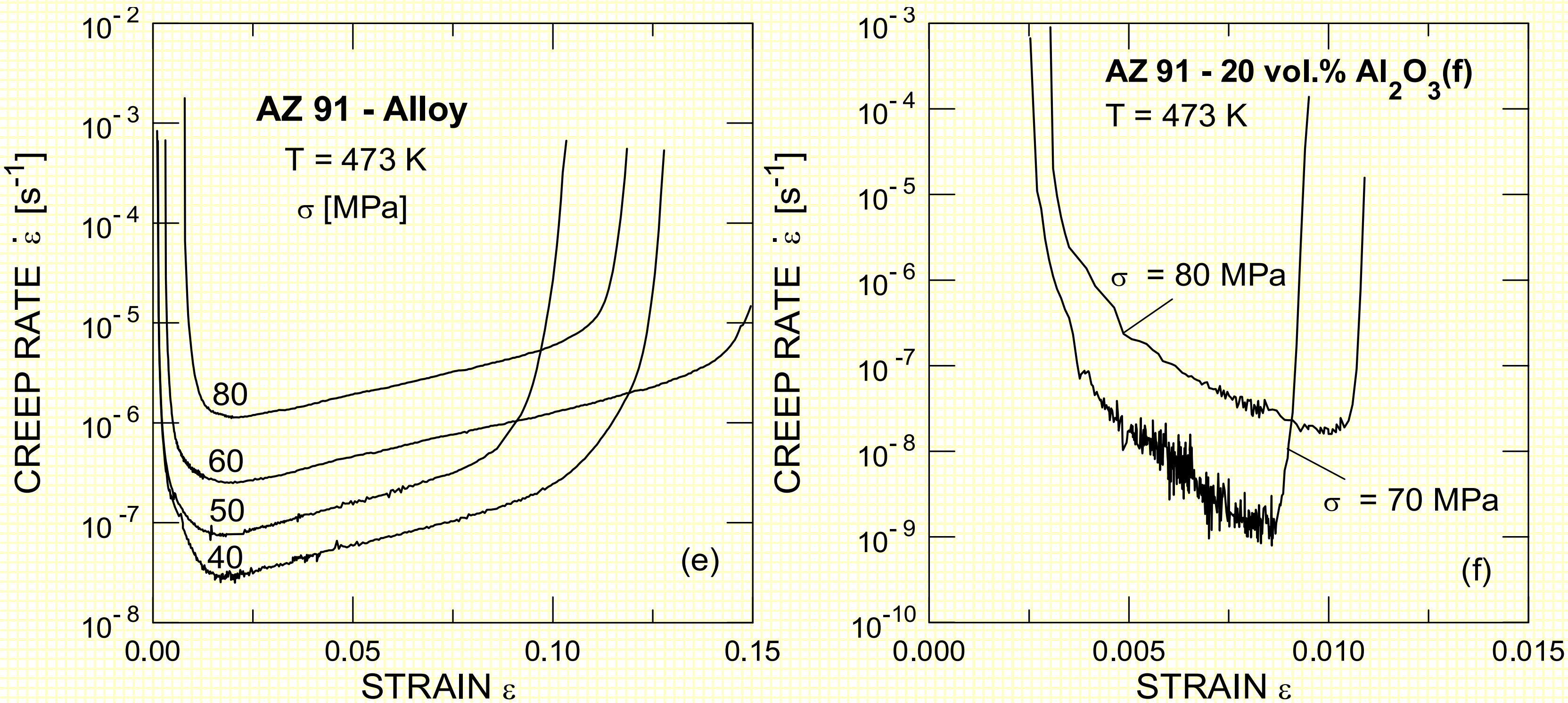
Creep curves for AZ 91 alloy and its composite at 473 K

CREEP CURVES



Time dependences of strain rate for AZ 91 alloy and its composite at 473 K

CREEP CURVES

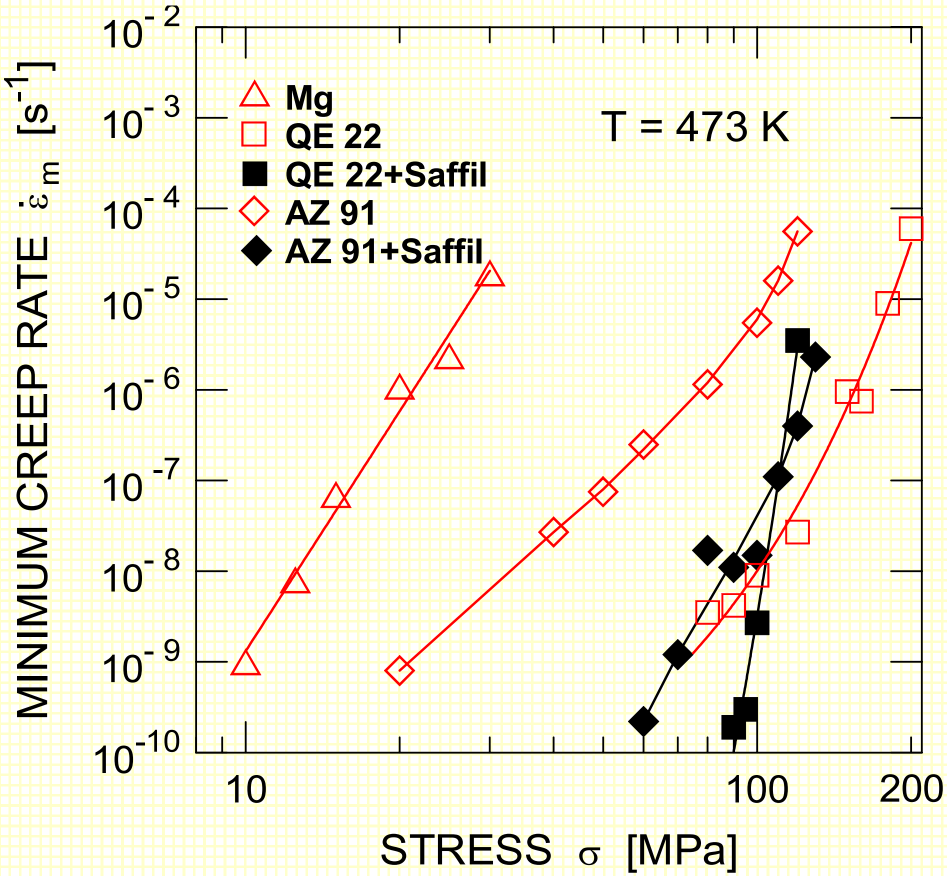


MONOLITHIC ALLOY

COMPOSITE

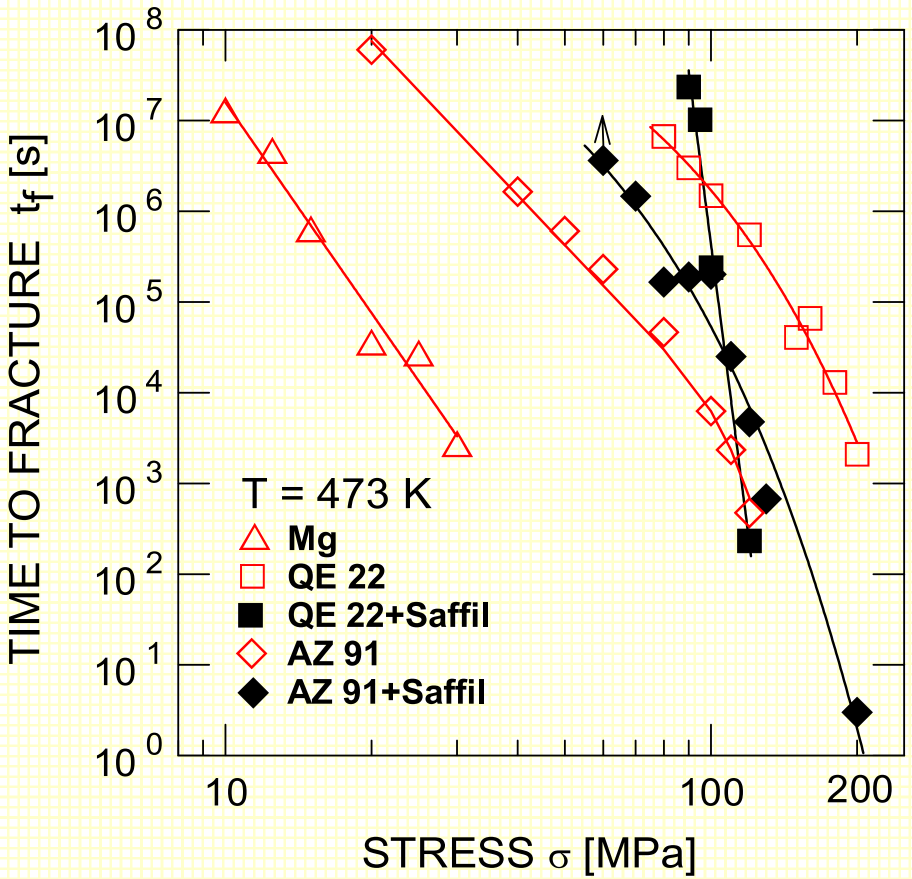
Dependences of strain rate on strain for AZ 91 alloy and its composite at 473 K

CREEP RESULTS



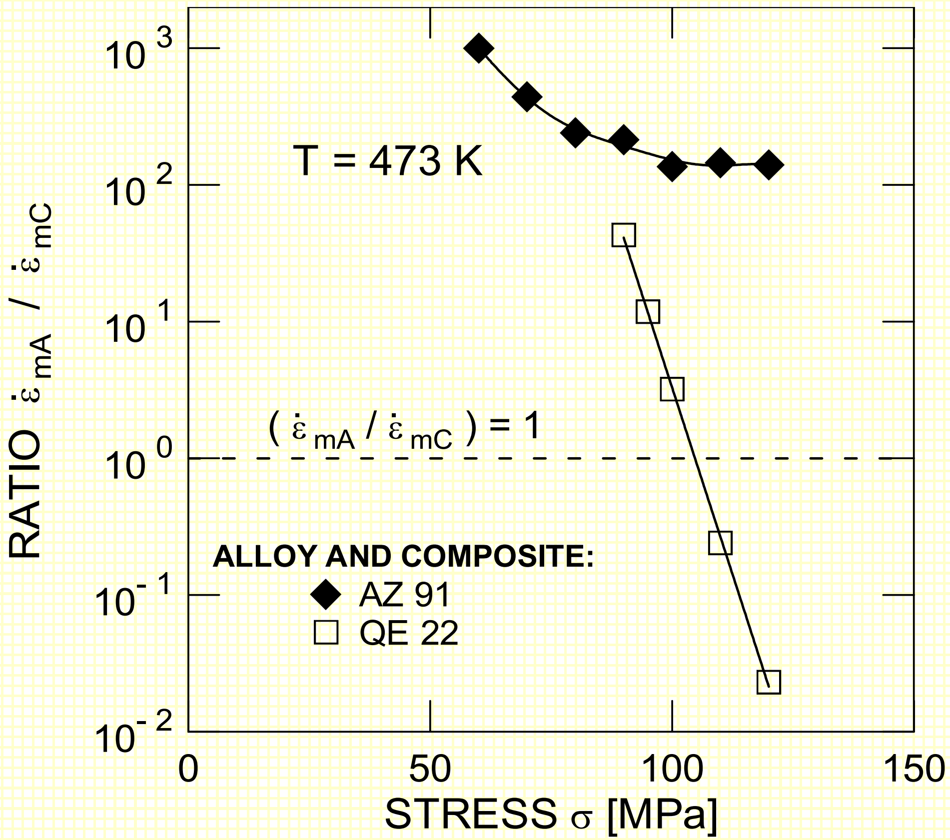
Minimum creep rate versus stress for the monolithic alloys and their short-fibre composites

CREEP RESULTS



Time to fracture versus stress for the monolithic alloys and their short-fibre composites

CREEP RESULTS



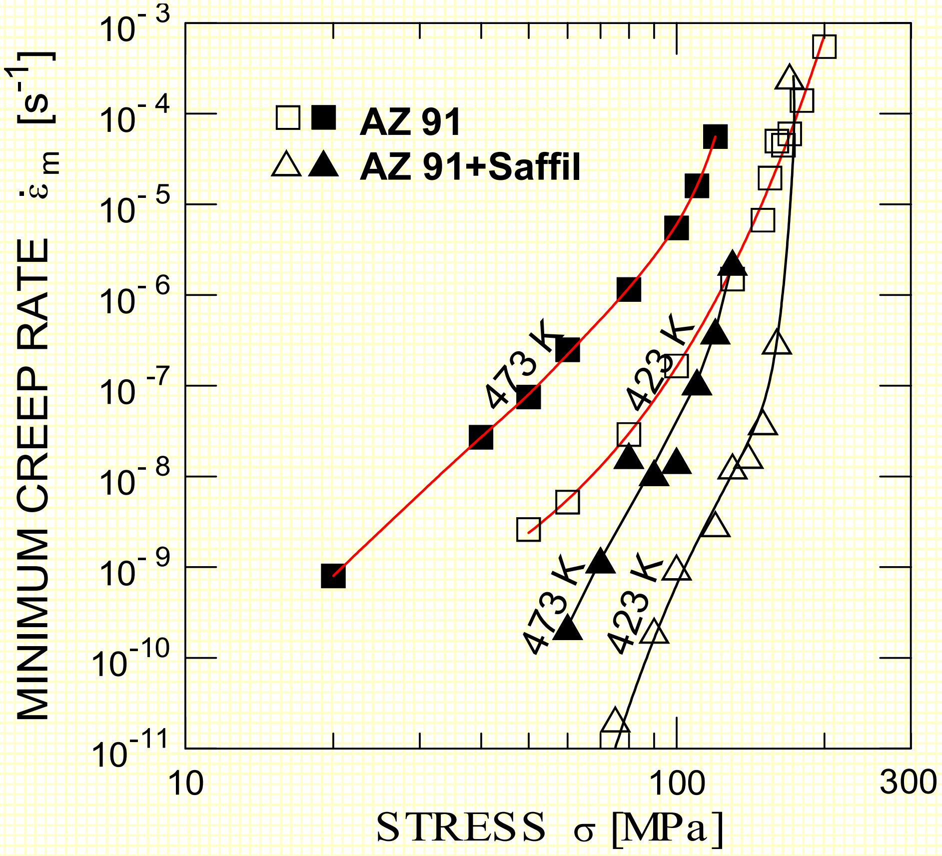
Effect of composite strengthening demonstrated by the ratios of minimum creep rate of the monolithic alloy and the composite

What

WHAT IS (ARE) THE REASON(S) FOR BETTER CREEP RESISTANCE OF THE COMPOSITE?

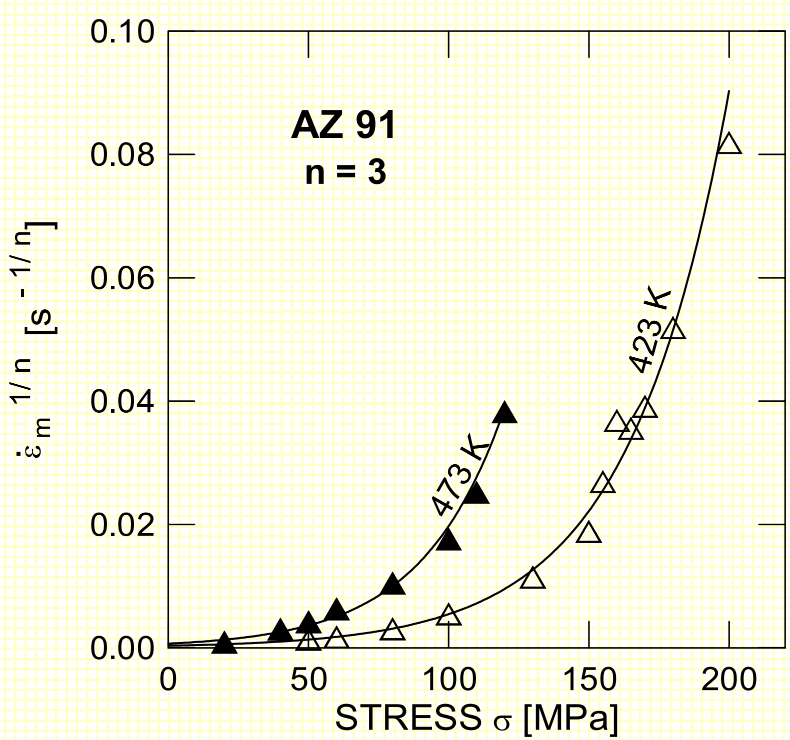
WHAT IS THE LIMITING FACTOR OF SHORT-FIBRE REINFORCEMENT?

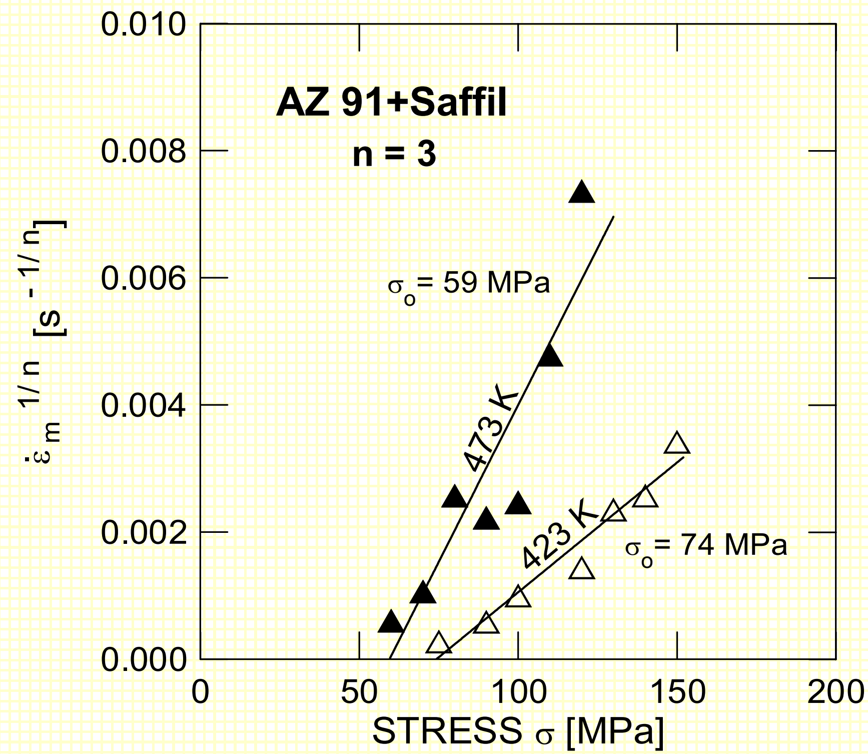
CREEP RESULTS



Stress dependences of minimum creep rate for the AZ 91 alloy and the AZ 91 – 20 vol.% Al_2O_3(f) composite at 423 and 473 K

THRESHOLD STRESS





Determination of the threshold stress for:

AZ 91 alloy
(no threshold stress)

AZ 91 – Saffil composite

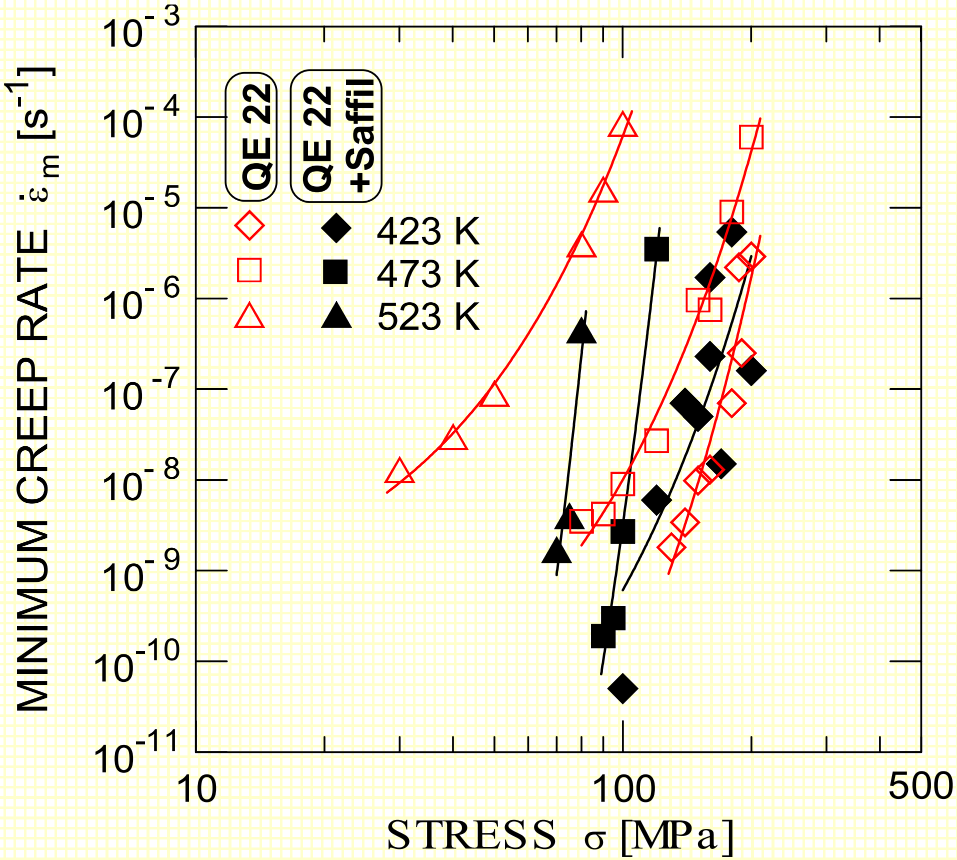
LOAD TRANSFER

The values of α (a load transfer coefficient)

$$\dot{\varepsilon}_c / \dot{\varepsilon}_m = (1-\alpha)^n \qquad n = 3$$

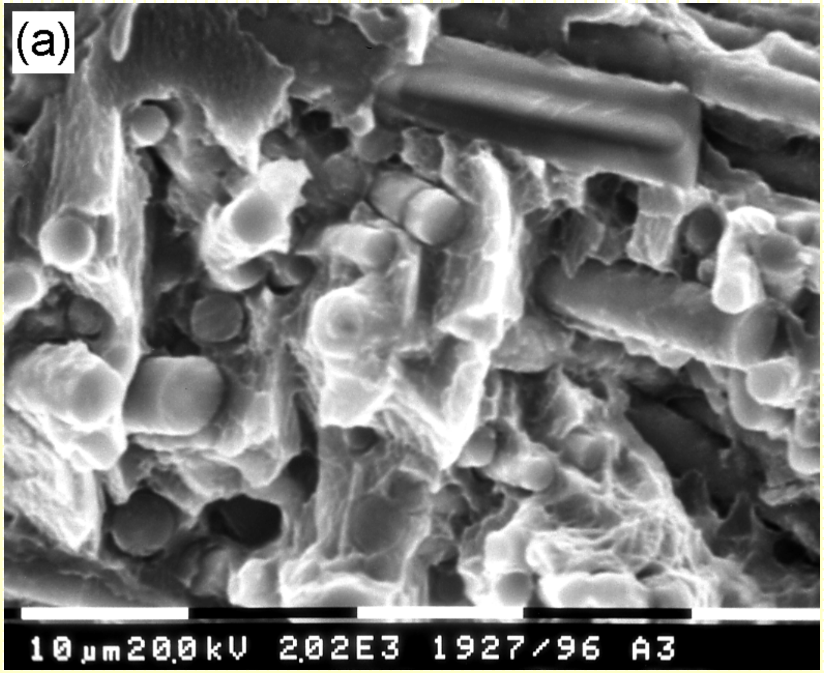
T [K]	σ [MPa]	$\dot{\varepsilon}_c$ [s^{-1}]	$\dot{\varepsilon}_m$ [s^{-1}]	α
423	90	2.45/-10	1.1/-7	0.869
	100	6.97/-10	2.34/-7	0.856
	125	6.4/-9	1.15/-6	0.822
	150	3.9-8	4.27/-6	0.790
473	50	7.5/-11	8.61/-8	0.904
	70	1.36/-9	5.48/-7	0.864
	90	1.18/-8	2.18/-6	0.824
	100	2.94/-8	3.89/-6	0.803

CREEP RESULTS

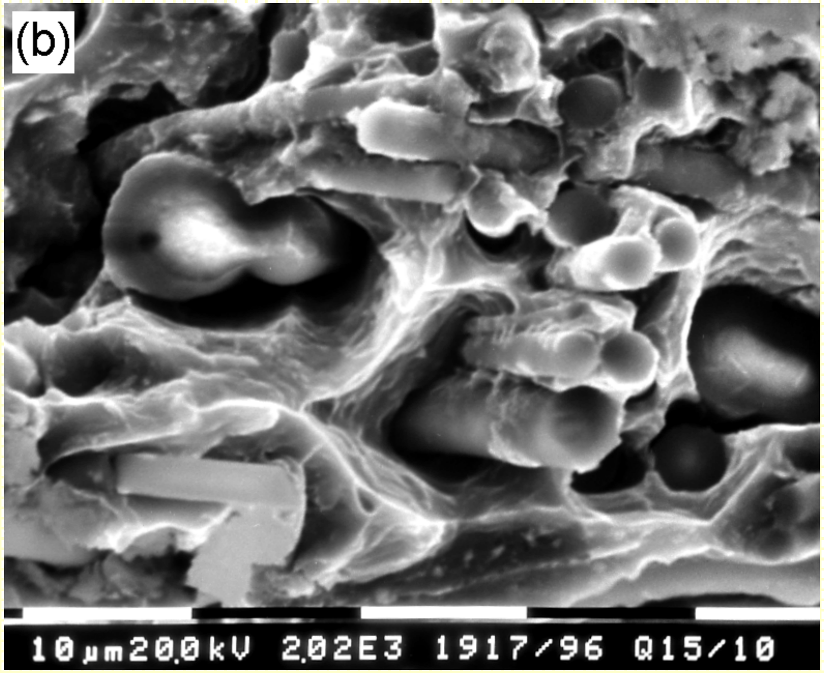


Stress dependences of minimum creep rates for the QE 22 alloy and the QE 22 – 20 vol.% Al_2O_3(f) composite at 423, 473 and 523 K

CREEP FRACTURE SURFACES (SEM)



AZ 91 + 20 vol.% COMPOSITE



QE 22 + 20 vol.% COMPOSITE

CONCLUSIONS I

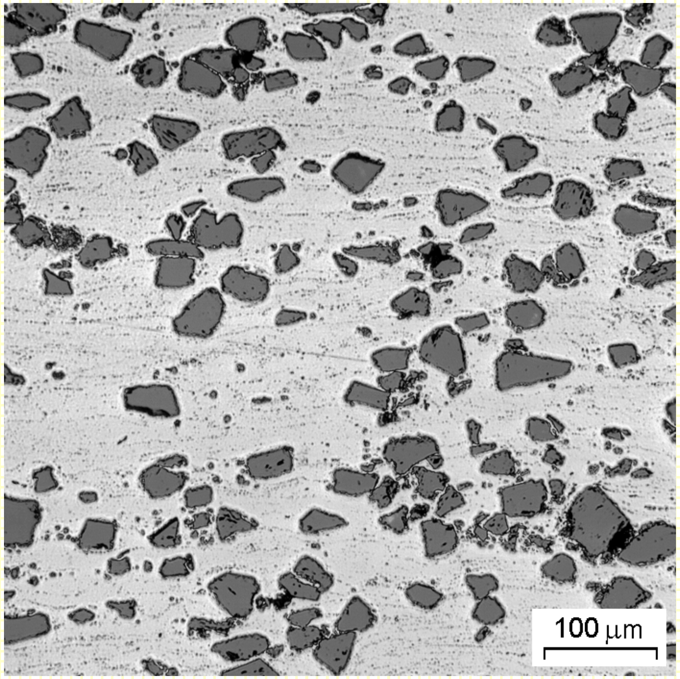
Short-fibre reinforced AZ 91 and QE 22 alloys

- The creep resistance of squeeze cast AZ 91 and QE 22 magnesium alloys reinforced with 20 vol.% Al2O3 short fibres (Saffil) is shown to be considerably improved compared to unreinforced matrix alloy.

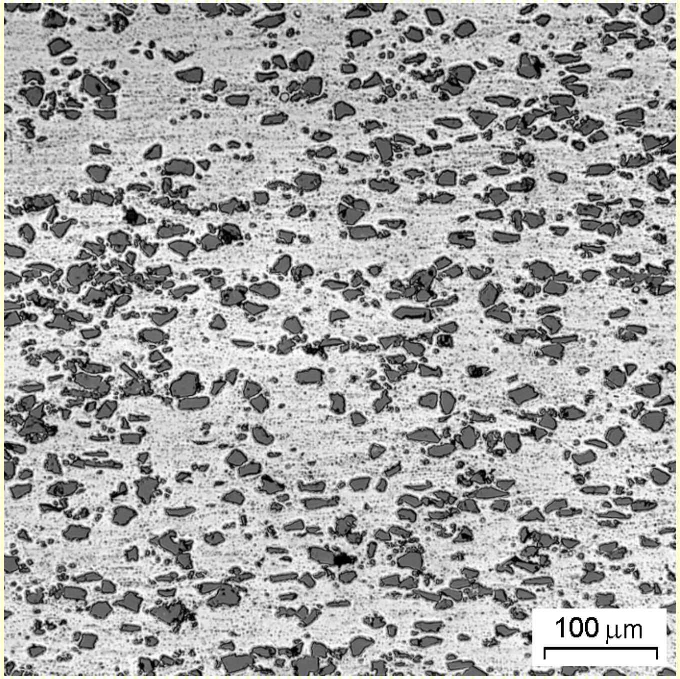
- The matrix microstructure may influence the creep properties of the composite. The synergetic effects of microstructural changes are expected as factors governing the creep flow in the matrix of QE 22 composite.

- Creep strengthening in the composite arises mainly fom:
  (a) load transfer in which part of the external load is transferred to the reinforcement with a corresponding reduction in the level of the effective stress on the material, and
  (b) the existence of a temperature-dependend threshold stress.

QE 22 + 15 vol.% SiC COMPOSITE



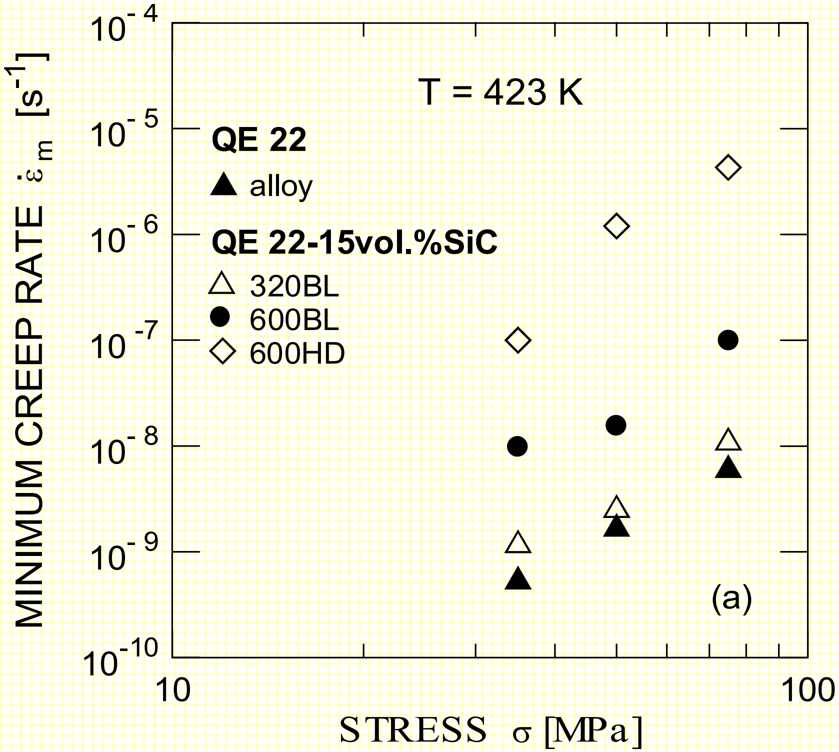
320 BL, 30 µm



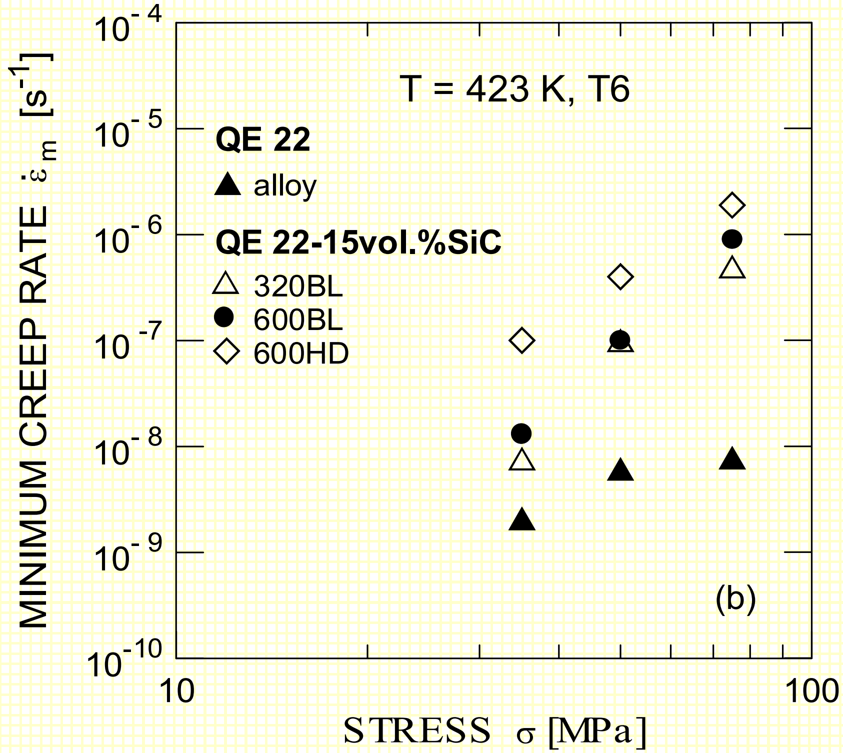
600 BL, 9 µm

Optical micrographs showing microstructure of QE 22 + SiC composites with different SiC particles

CREEP RESULTS



as received state

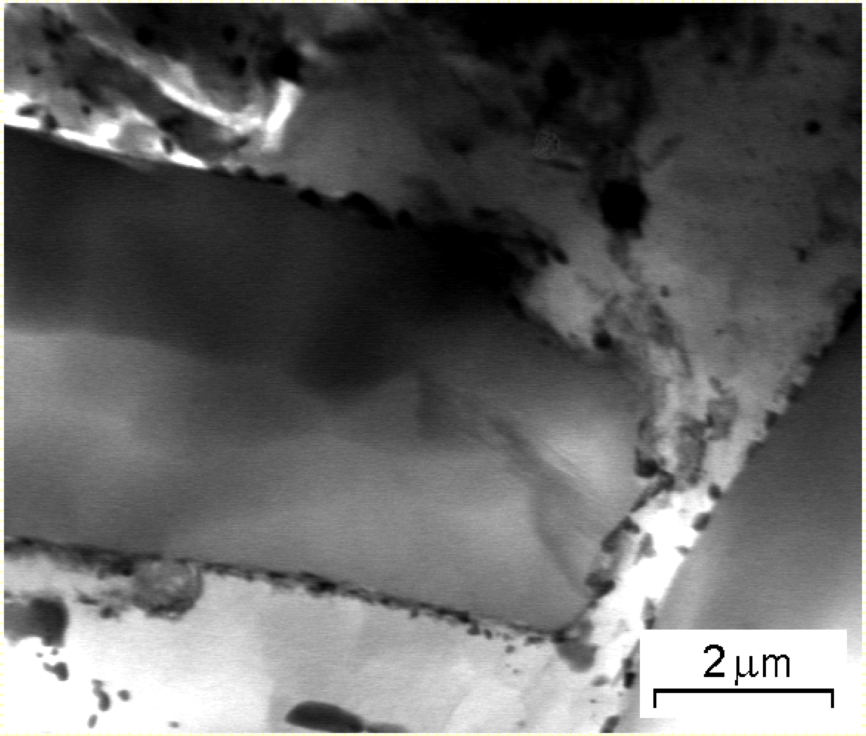


after T6 heat treatment

Stress dependences of minimum creep rates for the QE 22 alloy and the QE + 15 vol.% SiC composite at 423 K

MICROSTRUCTURE

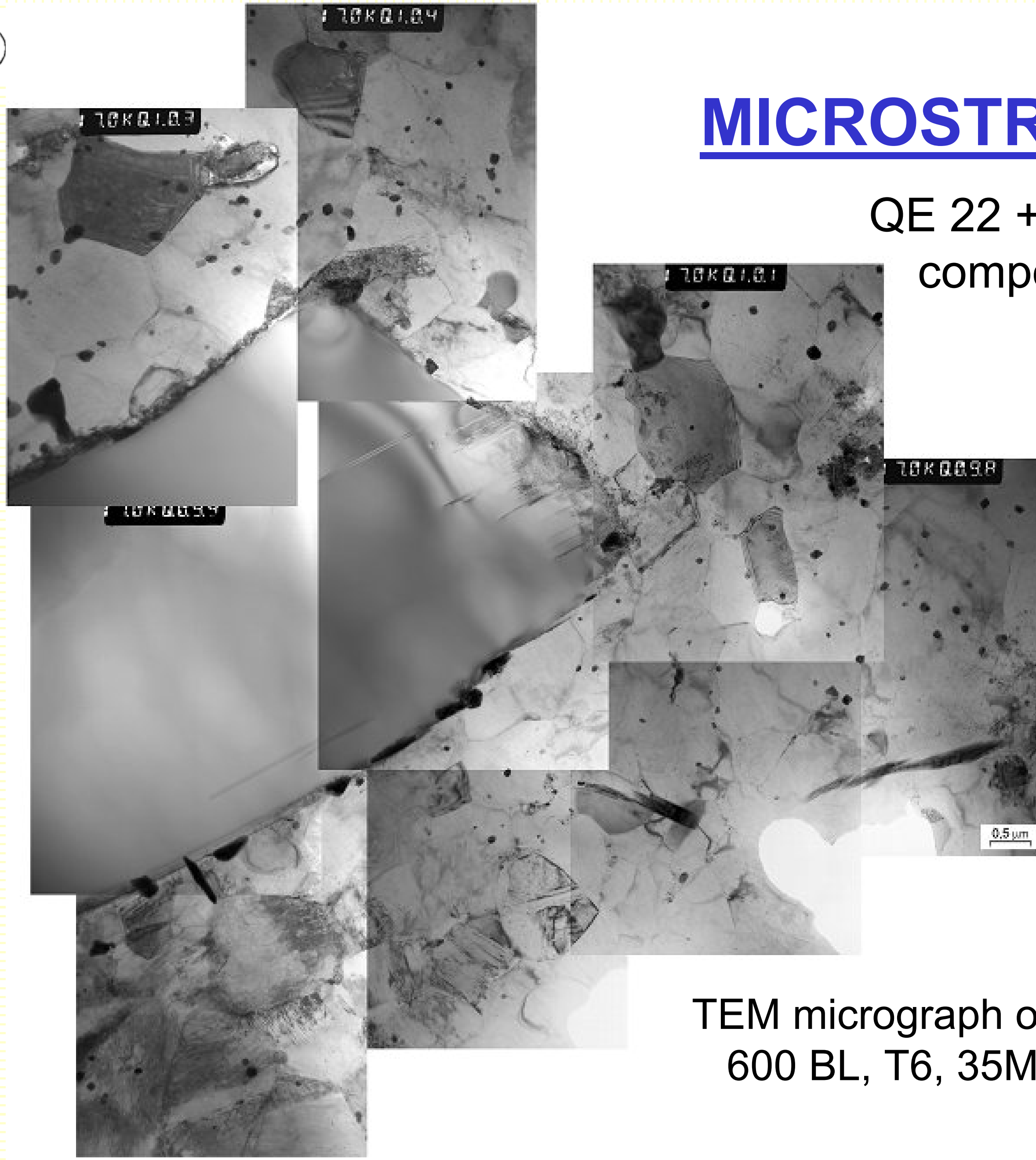
QE 22 +15 vol.% SiC (p) composite after creep



STEM micrograph of SiC particle. 600 BL, T6, 35MPa, 200 °C.

MICROSTRUCTURE

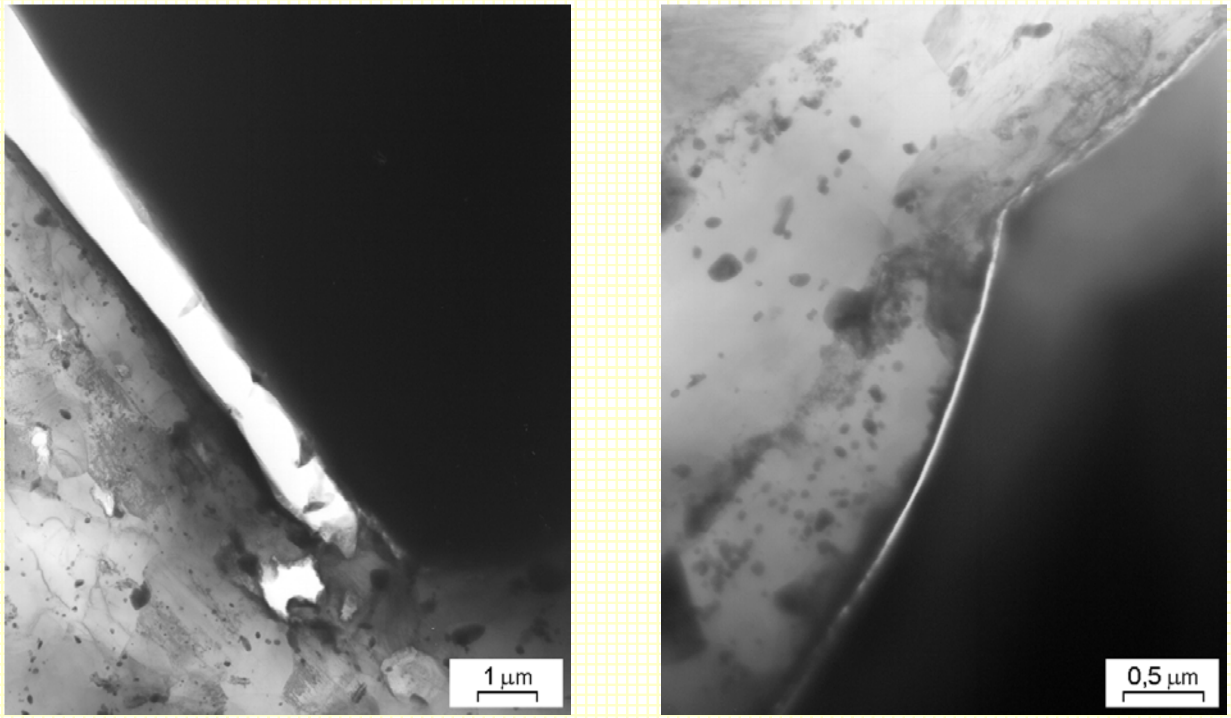
QE 22 +15 vol.% SiC(p)
composite after creep



TEM micrograph of SiC particle.
600 BL, T6, 35MPa, 200 °C.

MICROSTRUCTURE

QE 22 +15 vol.% SiC (p) composite after creep



TEM micrographs showing crack at matrix/SiC interface.
320 BL, T6, after creep.

CONCLUSIONS II

Particle reinforced QE 22 – SiC composite

An inferior creep resistance of the particle reinforced powder metallurgy QE 22 – 15 vol.% SiC (p) composite by comparison to the monolithic alloy is explained by following differences in the composite matrix microstructure:

- Enhanced precipitation of Nd-rich phases at the SiC/matrix interfaces in the QE 22-SiC composite after T6 heat treatment and during creep. Matrix depletion due to interfacial precipitation in the composite can produce precipitate inhomogeneity and deficiency in the matrix precipitate structure leading to the composite weakenining.

- Debonding and decohesion of the SiC/matrix interfaces due to the nucleation and growth of creep cavities and/or microcracks.

Last

THE RESULTS INDICATE A DOMINANT IMPORTANCE

OF THE CHOICE OF THE COMPOSITE MATRIX ALLOY

AND THE REINFORCEMENT USED IN COMPOSITE DESIGN !